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Effects of foliar applications of urea on apple trees

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EFFECTS OF FOLIAR APPLICATIONS
OF UREA ON APPLE TREES

by

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TABLE OF CONTENTS

INTRODUCTION

It has been known for the last few years that fertilizers can be applied in spray form to some plants as an immediate remedy for certain nutrient deficiencies. Iron or zinc deficiencies can be remedied readily by spraying the plants with iron or zinc sulfates.

Nitrogen fertilizers have been used by numerous workers in the United States for foliar applications on horticultural plants, using both inorganic and organic nitrogenous compounds. Urea, an organic nitrogen compound with 47 percent of nitrogen, was found to be the least injurious to apple leaves, and most effective.

This experiment was undertaken by the author to study the effects of foliar application of urea on Fireside apple leaves. The objective of this experiment is twofold;

1. To study the rate of nitrogen absorption by apple leaves when urea is applied to the foliage.

2. To determine the effects of sucrose and phosphorus on the absorption of nitrogen by apple leaves.

REVIEW OF LITERATURE

Hamilton et al. (6) were perhaps the first to report on foliar application of nitrogenous compounds. They sprayed apple trees with various nitrogenous compounds mixed with wettable sulfur, lime, and arsenate of lead, in a study of the possibilities of including nitrogen fertilization with pesticide sprays. Nitrogen content of the leaves was determined and reported as percentage of dry weight. Trees receiving four sprays containing 5 pounds of urea per 100 gallons of water showed a significant increase of about 0.2 percent nitrogen over the checks. Since this treatment caused no "burning" of leaves, they suggested the possibility of the regular use of urea in foliar sprays.

Late spraying with urea (30 days after blooming) resulted in a delayed formation of red color of the fruit. This delay might have been due to a high nitrogen level retarding the differentiation of pigments.

Fisher et al. (3) treated McIntosh apple trees with various dosages of both soil and foliar applications of urea. Chlorophyll content, growth rates, and fruiting were observed as possible indicators of the nitrogen nutrition of the trees, which was found to be improved by both soil and foliar applications. Soil applications of urea were made in the early spring, and the first foliar spray was applied at the petal fall stage. When trees that received soil or foliar applications of the same quantity of urea were compared, a better coloring of fruit was produced by the latter, but the former gave both higher chlorophyll content and higher yield of fruit.

When six sprays totalling six pounds of urea per tree were applied, the chlorophyll content was comparable to a three pound soil application, but a greater yield was obtained with the soil application. Both treatments delayed coloring of fruits. Delay from the spray may have been due to late application in the middle of August.

In 1948 and 1949, the same experiment was carried on by Fisher and Cook (4) with slight variation in treatments; NuGreen (44 percent organic nitrogen) was used in all spray treatments. Their results showed that there were no significant differences in nitrogen and chlorophyll content of leaves of soil and foliar treated plants, but both nitrogen and chlorophyll increased with increasing amounts of urea.

When a soil application of three pounds of urea was compared with four sprays of NuGreen of the same poundage, no significant difference was found either in growth or yield. When six pounds of urea were applied to the soil the yield was increased, but the percentage of fancy fruits was reduced.

Hamilton et al. (6) mixed urea sprays with wettable sulfur, lime and lead arsenate and obtained a significant increase in the nitrogen content of the leaves together with successful pest control. Wentzler and White (13) applied NuGreen and four nitrogenous pesticides, Fermate, Crag 341, Parathion and phenothiazone, as foliar sprays on two-year-old apple trees. Although insects and diseases were controlled, no increase of chlorophyll content was observed. A second experiment was carried out with mature apple trees and mixed sprays. McIntosh apple trees showed a higher content of chlorophyll with both Crag 341 and Fermate treatments alone. With Stayman Winesap trees the chlorophyll content was higher with NuGreen plus Crag 341 treatment than either NuGreen plus sulfur or Fermate treatment, but no significant difference was found between the former and the checks. They stated that possibly there was a depression of chlorophyll formation by sulfur.

Emmert and Klinker (2) made a study of mixed sprays of sucrose and urea on tomato plants. They found that a solution equi-molar in sucrose and urea stopped leaf burning and permitted the use of ten times as much urea (50 pounds per 100 gallons of water) on tomato plants as when no sucrose was used.

Haas (5) sprayed water cultured lemon trees with a mixture of 45 pounds urea and 2.5 pounds of hydrated lime to 100 gallons of water. The leaves of nitrogen deficient trees recovered to dark green color without burning, while marginal burning resulted from urea sprays alone.

Weinberger et al. (12) carried out urea spray experiments on four varieties of peach trees. Two levels of urea, five and ten pounds per 100 gallons of water, were used, but no significant difference was found in the nitrogen content of the leaves or in the coloring of the fruit. Twenty-five and 50 pounds of urea per 100 gallons of water still did not increase leaf nitrogen content.

Patterson (7) made a survey study of the response of sand cultured tomato and beet plants to urea sprays. A moderately better growth resulted from urea sprays, but plants getting the additional nitrogen through the roots were far superior in size, color and set of fruit to any receiving it through the leaves.

Staten (11) used urea sprays on cotton plants and observed for leaf burning and yield of treated plants. When solutions containing more than 2 percent urea were used, slight chlorosis and thickening of the leaves resulted. Urea solutions of 3½ to 5 percent caused leaf burning. An increase in yield of 2.8 pounds of lint cotton per pound of nitrogen sprayed on the leaves was secured as compared with 0.69 pounds of lint cotton per pound of nitrogen applied through the soil.

A general study of the responses of various fruit trees to foliar applications of NuGreen was made by Proebsting (8). Spray solutions were made to a standard concentration of five pounds of urea to 100 gallons of water. As found by other workers, apple trees showed good response to NuGreen sprays without injury to the leaves. Some stone fruits, including sweet cherry, apricot, peach and almond failed to respond to the sprays. Figs showed visible benefit in leaf color and in the rapidity of recovery from a spring freeze with NuGreen sprays. Tests of foliar sprays of NuGreen on walnuts and olives showed possibilities of using in practice.

Proebsting suggested that urea sprays have a place as a supplement to, or as a replacement for the standard method of soil application of nitrogen fertilizer for apples. Pound for pound of actual nitrogen, urea spray is a more efficient method, and the response is much more rapid than to soil applications. Since urea can be included with other materials which are sprayed on the plants, the cost of application is negligible. It should be possible to regulate the nitrogen status of the trees more accurately than is possible by soil applications alone.

MATERIALS AND METHODS

Plant Materials

Two-year-old nursery grown, root grafted, Fireside apple trees were used in these studies. The trees were headed back to induce vigorous growth, and were planted in four-gallon porcelain crocks in a soil mixture of three parts loam and one part sand.

The trees were grown in the greenhouse throughout the winter and spring of 1950-51, and were moved outside in the summer of 1951 and back to the greenhouse in the fall of 1951.

Several sprays of Nicofume and Parathion were applied to the trees to control aphids and red spiders. About 30 g. of Ra-Pid-Gro fertilizer (23-21-17) was applied to each crock in early summer of 1951.

Experimental Design

Two foliar applications were made in 1951 to study the absorption of nitrogen when applied on apple leaves. The first applications were made on April 9, 1951. A 5x3 factorial design was used with treatments of five urea concentrations and three sugar concentrations with two replications. The trees within each replication were randomized.

Table 1. Urea, Ra-Pid-Gro and sucrose concentrations used in spring applications

Nitrogen / Sucrose	N_o (No nitrogen)	N_1 (0.1M Urea)	N_2 (0.2M Urea)	N_4 (0.4M Urea)	N_1' (12.18g/L. Ra-Pid-Gro)
S_o (No Sucrose)	N_oS_o	N_1S_o	N_2S_o	N_4S_o	$N_1'S_o$
S_1 (0.1M Sucrose)	N_oS_1	N_1S_1	N_2S_1	N_4S_1	$N_1'S_1$
S_4 (0.4M Sucrose)	N_oS_4	N_1S_4	N_2S_4	N_4S_4	$N_1'S_4$

The second set of foliar applications was made on October 28, 1951. A design of a 3x2 factorial was used with three urea concentrations and two sucrose concentrations. Three trees per treatment were used, and the 18 trees were completely randomized.

Table 2. Urea and sucrose concentrations used in fall applications.

Nitrogen / Sucrose	N_o (No nitrogen)	N_1 (0.1M Urea)	N_2 (0.2M Urea)
S_o (No Sucrose)	N_oS_o	N_1S_o	N_2S_o
S_4 (0.4M Sucrose)	N_oS_4	N_1S_4	N_2S_4

Sampling Methods

In the spring applications 0.1 percent Dreft was added to the chemical solutions as a wetting agent. The solutions were transferred to numbered beakers and weighed together with small camel's hair brushes on a torsion balance.

A vigorously growing branch with 10 to 20 leaves was selected on each tree. The leaf areas were measured by the length by width method (p. 10). The solutions were painted on both sides of the leaves with the camel's hair brushes. The beakers and brushes were then reweighed to compute the amount of solution applied to the leaves. Several leaves were sampled from the branch at time intervals of 0, 12 and 48 hours after painting.

In the fall applications, a small atomizer was used to apply the solutions to both sides of the leaves. The solutions again contained 0.1 percent Dreft. Two uniform leaves of known area were taken from each branch at 0, 6, 12 and 24 hours after treatment.

Laboratory Methods

All leaf samples were washed and both leaves and wash solutions were analyzed for total N, for a study of the nitrogen absorption.

A modification of the washing method suggested by Smith et al. (9) was used. The leaf samples were immediately taken into the laboratory and washed twice in 1.0 percent Dreft, twice in tap and twice in distilled water. The washings were combined in a 250 ml.

volumetric flask and made to volume. The wash solutions were stored at 4° C. to reduce growth of microorganisms.

The washed leaves were placed in paper sacks and dried in an oven at 100° C. for 24 hours, ground in a Wiley mill, and stored in stoppered vials under dry, cool conditions.

All wash solutions were analyzed for total nitrogen by the Kjeldahl method. Duplicate determinations were made using two 50 ml. aliquots from each solution. The leaves were analyzed for total N by the same method, using 50-100 mg. of leaf material per sample.

Leaf Area Measurements

Boynton and Harris (1) made a study of the correlation between leaf area of McIntosh apple trees, measured with a planimeter, and the product of maximum length and width of the same leaves. They found a very close correlation between these two measurements and, therefore, the length by width method could be used as an adequate measurement of the actual leaf area of McIntosh apple trees.

The author made a study of the correlation of the above two methods on Fireside apple trees. Eighteen young leaves were taken at random from several Fireside trees and their outlines traced on paper. Subsequently, the areas were measured with a planimeter.

The maximum length and width of each leaf was recorded with the area, and the correlation and regression coefficients were calculated by using the method described by Snedecor (10).

Table 3. Actual leaf area and length x width of Fireside apple leaves.

No.	Length x width (cm^2) X	Actual leaf area (cm^2) Y
1	38.27	27.04
2	45.60	29.10
3	58.41	39.00
4	42.09	27.93
5	43.50	28.51
6	41.50	28.81
7	41.10	27.24
8	49.92	36.94
9	49.90	31.45
10	43.70	31.85
11	26.70	19.89
12	47.84	31.55
13	36.10	23.52
14	43.20	30.40
15	37.00	25.87
16	30.80	20.77
17	32.93	22.73
18	44.90	30.87

Table 4. Relationship between the actual area and the (length x width) of young leaves of two-year-old Fireside apple trees.

Correlation	Number of comparisons	Correlation coefficient	Regression coefficient*
Leaf area versus (length x width)	18	0.96**	0.68

* See also Fig. 1.
** Significant at 1 percent level.

The correlation between these two methods is very high (Table 4, Fig. 1), showing that the length by width method can be used as an adequate measurement of actual leaf area on Fireside apple trees. Since the regression line passes through the origin, the actual leaf area is given by multiplying (length x width) by the regression coefficient, 0.68.

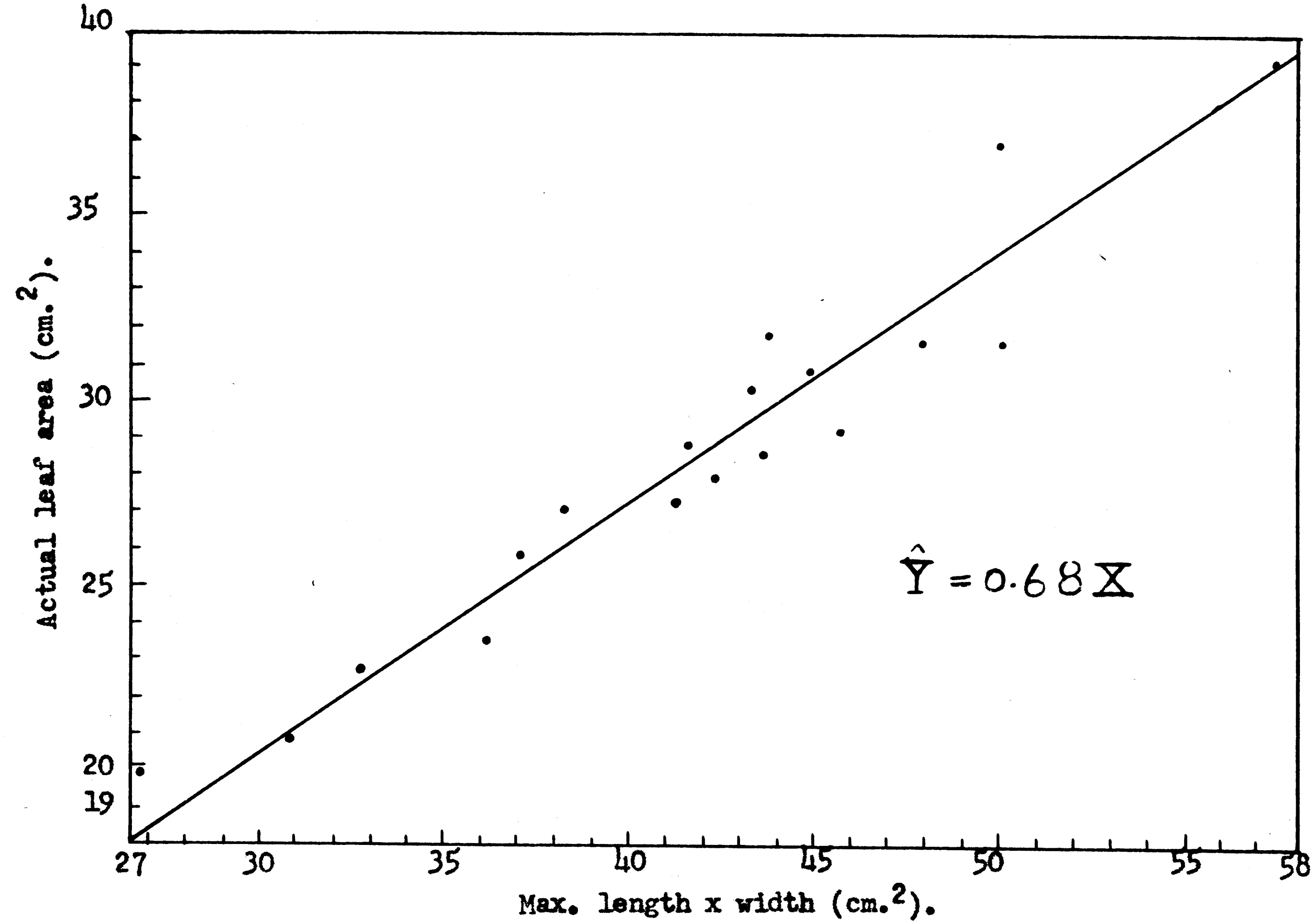

Fig. 1. Regression of actual leaf area (cm.^{2}) on length x width (cm.^{2}) of Fireside apple leaves.

RESULTS

Nitrogen applied and absorbed per dm.^{2} leaf area of the spring applications is shown in Table 5, where S_0 to S_4 represents rate of sucrose and N_0 to N_4 rates of nitrogen application. N_1' was Ra-Pid-Gro.

Slight marginal burning was found on all leaves treated with 0.4M (N_4) urea, with or without sucrose; very slight tip burning with 0.2M (N_2) urea, with or without sucrose; but there was no visible burning of the leaves with 0.1M urea and with Ra-Pid-Gro at 12.18 g. per liter of solution.

An analysis of variance of the data in Table 5 is shown in Table 6. The sum of squares attributed to different nitrogen treatments was highly significant, indicating that the absorption of nitrogen was affected by treatments. Since this difference in absorption might have been due to different amounts of nitrogen applied on the leaves, a covariance analysis was made of the amount of N applied and the amount of N absorbed after 12 hours as affected by sucrose (Table 7). The F value indicates that all of the treatment differences were due to N rates and none to sucrose.

Three regression lines were plotted for the three sucrose levels, with N absorbed after 12 hours against N applied. The regression lines are very close together. A test of significance of the differences between adjusted means of the regressions for the sucrose level is included in the covariance study (Table 7). The non-significant F value shows that sucrose levels did not affect the absorption of nitrogen by the leaves.

Table 5. Amount of N applied (mg./dm.^{2}) and absorbed by Fireside apple leaves in the spring foliar applications.

		S_oN_o	S_oN_1	S_oN_2	S_oN_4	S_oN_1'	S_1N_o	S_1N_1	S_1N_2	S_1N_4	S_1N_1'	S_4N_o	S_4N_1	S_4N_2	S_4N_4	S_4N_1'
N applied	Rep. 1	0	2.29	6.50	8.75	2.33	0	2.98	5.76	15.00	3.02	0	3.19	5.77	15.25	3.58
(mg./dm.^{2})*	Rep. 2	0	2.24	5.94	9.52	2.88	0	2.88	4.20	11.54	3.39	0	3.78	6.55	8.74	2.88
N absorbed at 12 hrs.	Rep. 1	0	1.83	3.47	6.26	1.57	0	2.01	4.23	13.18	2.59	0	2.82	4.65	12.08	2.79
(mg./dm.^{2})**	Rep. 2	0	2.05	4.94	7.48	2.49	0	1.81	2.13	9.42	3.05	0	3.37	5.95	6.98	2.88
N absorbed at 48 hrs.	Rep. 1	0	2.29	5.75	7.35	2.17	0	2.45	4.66	13.05	2.76	0	3.19	4.46	13.77	3.19
(mg./dm.^{2})**	Rep. 2	0	1.98	4.78	7.71	2.27	0	2.88	3.20	9.47	3.39	0	3.78	5.15	6.96	2.64

$$* \text{ N applied (mg./dm.}^2) = \frac{\text{g. solution applied x mg. N per g. solution}}{\text{Leaf area (dm.}^2)}$$

$$** \text{ N absorbed (mg./dm.}^2) = \text{N applied} - \frac{\text{Total mg. N in wash solution taken at sampling time}}{\text{Leaf area (dm.}^2)}$$

Table 6. Analysis of variance of absorption of N (mg./dm.^{2}) from table 5.

(Treatments S_0N_0, S_1N_0, S_4N_0 have been excluded.)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Reps.	1	5.2074	5.2074	
Treatment				
Nitrogen	3	380.7228	126.91	55.52**
Sucrose	2	14.2197	7.11	3.11[1]
Nitrogen x sucrose	6	30.5629	5.09	2.23[2]
Time	1	1.7902	1.7902	
Treatment x time	11	2.1431	0.1948	
Error	23	52.5741	2.2858	

** Significant at 1% level.

[1] Significant F at 5% level = 3.42.

[2] Significant F at 5% level = 2.53.

Table 7. Test of significance of adjusted sucrose means of N applied (mg./dm.^{2}) and N absorbed (mg./dm.^{2}) after 12 hours by leaves of Fireside apple trees.

Source of variation	Degrees of freedom	Sum of squares and products			Errors of estimate		
		Sx^2	$S\,x\,y$	Sy^2	Sum of squares	Degrees of freedom	Mean square
Total	23	341.6304	280.5482	238.6222			
Reps.	1	4.0673	2.0295	1.0127			
Sucrose	2	6.5195	7.4374	8.7352			
Nitrogen	3	289.9507	231.4907	185.8860			
Sucrose x nitrogen	6	15.3651	15.8384	18.3241			
Error	11	25.7278	23.7522	24.6642	2.7359	10	0.2736
Sucrose + Error	13	32.2473	31.1896	33.3994	3.2328	12	
Difference for testing adjusted sucrose means					0.4969	2	0.2485

$$F = \frac{0.2485}{0.2736} = 0.91$$

In order to determine whether all the observations are from a common regression population, a test of significance of regression was then made (Table 8) and the highly significant F value indicates that the sum of squares of error was largely due to common regression.

Table 8. Test of significance of regression of N absorbed (mg./dm.^{2}) after 12 hours on N applied (mg./dm.^{2}).

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Regression	1	21.9283	21.9283	72.13**
Deviation from regression	9	2.7359	0.3040	

** significant at 1% level.

The regression equation was calculated and the regression line for absorption after 12 hours was plotted from the above data (Fig. 2). The regression between N applied and N absorbed after 48 hours is shown in Figure 3. Since the deviations from regression after 48 hours were smaller than the deviations from regression of N applied and N absorbed after 12 hours, no covariance analysis was made.

Nitrogen content of the leaf samples is shown in Table 9. An analysis of variance was made (Table 10) and only the F value of treatments showed significance. Since both time and treatment x

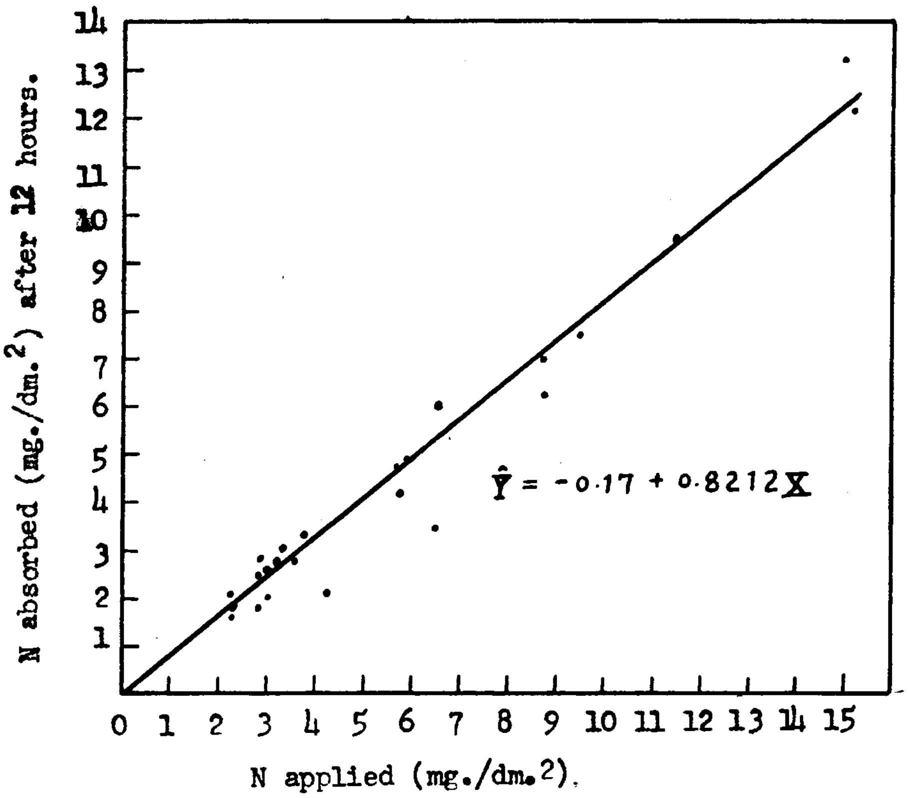

Fig. 2. Regression of N absorbed (mg./dm.^{2}) after 12 hours on N applied (mg./dm.^{2}) on apple leaves.

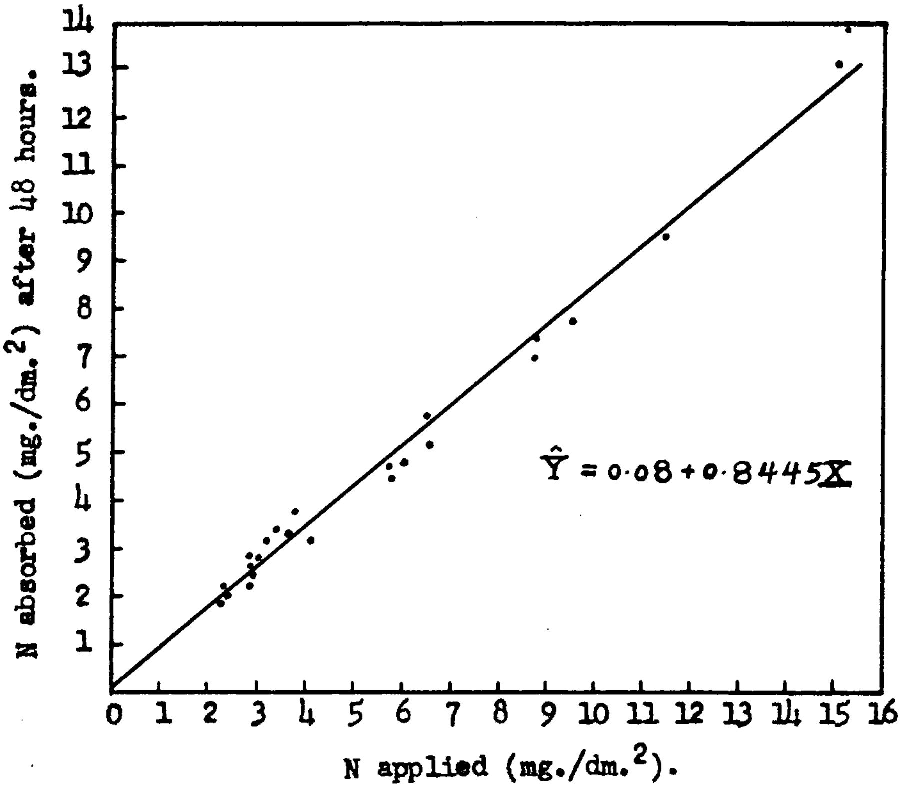

Fig. 3. Regression of N absorbed (mg./dm.^{2}) after 48 hours on N applied (mg./dm.^{2}) on apple leaves.

Table 9. Nitrogen content (mg./dm.^{2}) of Fireside apple leaves at spring applications.

		S_oN_o	S_oN_1	S_oN_2	S_oN_4	S_oN_1'	S_1N_o	S_1N_1	S_1N_2	S_1N_4	S_1N_1'	S_4N_o	S_4N_1	S_4N_2	S_4N_4	S_4N_1'
At time of	Rep. 1	18.1	19.1	18.2	22.2	17.2	17.5	17.3	18.7	20.9	19.3	17.4	18.6	14.8	19.8	16.5
applications	Rep. 2	19.5	17.0	18.7	17.9	19.3	16.0	19.3	17.2	21.1	15.4	19.0	21.7	20.7	19.1	19.2
12 hours after	Rep. 1	13.8	19.7	17.9	24.3	16.6	15.3	22.9	15.5	20.9	21.5	14.5	21.1	16.8	20.8	20.3
applications	Rep. 2	16.7	15.6	14.2	16.7	16.4	16.0	20.0	17.3	21.3	16.3	16.8	15.6	16.7	23.2	14.8
48 hours after	Rep. 1	15.8	21.4	20.8	22.0	16.5	17.8	16.8	18.2	23.5	19.3	15.9	20.2	18.7	23.2	16.3
applications	Rep. 2	19.1	19.8	14.1	21.3	17.8	21.9	22.3	21.3	23.0	14.4	15.0	21.4	22.0	21.1	19.1

time were non-significant, the large F value indicates that there was a difference in the nitrogen content of the leaves of different trees. No significant increase in nitrogen content could be attributed to the urea applications.

Table 10. Analysis of variance of N content (mg./dm.^{2}) of Fireside apple leaves.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Reps.	1	1.50	1.50	
Treatment	14	226.28	16.16	2.97**
Time	2	27.55	13.78	2.53[1]
Treatment x time	28	97.48	3.48	
Error	44	239.74	5.45	

** Significant at 1% level.

[1] Significant F at 5% level = 3.21.

The results of the fall foliar applications are presented in Table 11. The solutions were applied with an atomizer instead of a brush. An analysis of variance was made with all absorption values of the nitrogen treatments (Table 12). The results show that, in this application, sucrose increased the absorption of nitrogen by the leaves. In treatment S_4N_1, about 30 percent of the applied N was absorbed after 24 hours, and in treatment S_4N_2 about 38 percent was absorbed. These old, differentiated leaves are thus shown to differ in their response to urea sprays from the young leaves of the spring experiments, both by absorbing less nitrogen more slowly and by responding to sucrose applications.

Table 11. Amount of N applied (mg./dm.^{2}) and absorbed by Fireside apple leaves in the fall foliar applications.

Treatments			N_0	N_1				N_2			
		Tree No.	1, 17, 18	2	7	12	Mean	3	8	13	Mean
S_0	N(mg./dm.^{2}) applied		0	1.88	3.32	2.87	2.69	4.90	2.74	4.71	4.12
	N(mg./dm.^{2}) absorbed	6 hrs.	0	-0.08	0.45	0.78	0.38	0.26	-1.88	-2.32	-1.31
		12 hrs.	0	-0.04	0.33	0.03	0.11	-0.84	-1.23	-1.38	-1.15
		24 hrs.	0	-0.25	-0.01	0.85	0.20	-1.17	-0.73	-0.58	-0.83
		Tree No.	9, 5, 14	4	10	11	Mean	6	15	16	Mean
S_4	N(mg./dm.^{2}) applied		0	2.80	2.35	3.90	3.02	5.78	5.40	4.96	5.38
	N(mg./dm.^{2}) absorbed	6 hrs.	0	0.11	-0.12	0.79	0.26	0.56	-0.10	0.61	0.36
		12 hrs.	0	0.50	0.10	0.42	0.34	1.25	-0.75	1.78	0.76
		24 hrs.	0	1.11	0.66	0.94	0.90	2.22	1.69	2.24	2.05

$$\text{N applied (mg./dm.}^2) = \frac{\text{Total mg.N in wash solution taken after applications}}{\text{Leaf area (dm.}^2)}$$

$$\text{N absorbed (mg./dm.}^2) = \text{N (mg./dm.}^2)\text{ applied} - \frac{\text{Total mg.N in wash solution taken at 12 or 48 hours}}{\text{Leaf area (dm.}^2)}$$

Table 12. Analysis of variance of absorption of N (mg./dm.^{2}) from table 11.

(Treatments S_0N_0, S_4N_0 have been excluded.)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Main plots				
Treatment				
Nitrogen	1	1.3379	1.34	2.13
Sucrose	1	13.2253	13.23	21.00**
Nitrogen x sucrose	1	7.9524	7.95	12.62**
Reps. Error for (main plot)	8	5.0785	0.63	
Sub-plots				
Time	2	3.0567	1.53	6.38**
Treatment x time	6	3.9304	0.655	2.73[1]
Time x reps. (Error for sub-plot)	16	3.8398	0.24	

** significant at 1% level.

[1] significant F at 5% level = 2.74.

DISCUSSION

As described above (p. 13), some marginal burning was observed in the spring foliar applications with 0.2M and 0.4M urea treatments regardless of whether sucrose was added. This is comparable to the results obtained by Hamilton et al. (6); when a spray solution of five pounds of urea per 100 gallons of water (about 0.1M urea) was used, no leaf burning was observed. When a spray solution of 10 pounds of urea per 100 gallons of water (about 0.2M urea) was applied, leaf burning was found on McIntosh, Rome Beauty, and Cortland apple trees.

Emmert and Klinker (2) sprayed tomato leaves with concentrations of urea up to 1.0M and marginal burning was observed, but when equimolar sucrose was added to the urea solution, the burning was prevented. In our experiments only very minor burning resulted on apple leaves with 0.4M urea, and sucrose did not have the effect of preventing the burning.

In the covariance study of the nitrogen absorbed against nitrogen applied in the spring applications (Table 7, 8), the non-significant $\underline{F}$ value in the test of differences between adjusted sucrose means (Table 7) shows that sucrose did not affect the absorption of nitrogen by these young leaves.

The two regression lines of nitrogen absorbed after 12 and 48 hours against nitrogen applied (Fig. 2,3) indicate that these two variables are directly proportional. About 82 percent of applied nitrogen was absorbed after 12 hours, and 84 percent was absorbed after 48 hours; thus only 2 percent was absorbed during the period of 12-48 hours.

From the absorption data (Table 5), the Ra-Pid-Gro treatments did not differ from the 0.1M urea treatments. Since both had the same initial nitrogen concentration, it seems reasonable to assume that the phosphorus and potassium in Ra-Pid-Gro did not affect the absorption of nitrogen by the leaves. It seems that the lack of response to sucrose and phosphorus may reflect the condition of the leaves.

The analysis of variance of nitrogen absorbed by Fireside apple leaves in the fall applications is presented in Table 12. The significant _F_ value for sucrose indicates that there was a difference in nitrogen absorption at different sucrose levels; significant _F_ value of the interaction between nitrogen and sucrose probably means that, with sucrose added, the amount of nitrogen absorbed was proportional to the amount of nitrogen applied per unit leaf area.

The analysis of variance of the nitrogen content of Fireside apple leaves (Table 10) shows that there was a significant difference in the nitrogen content of the leaves of trees of different treatments in the spring experiments. Since the _F_ value for time fell just short of significance at the five percent level, it is concluded that even after the treatments were applied, no significant increase in nitrogen content of the leaves was obtained. This fact is rather surprising, since from the data of the wash solutions (Table 5), most of the applied nitrogen disappeared from the leaf surfaces after 12 hours, and may be taken as an indication of a rapid translocation of the absorbed nitrogen. Hamilton et al. (6), Fisher et al. (3), and Fisher and Cook (4) found that the nitrogen content of treated apple leaves was increased after 3-6 sprays of five pounds of urea per 100 gallons of water. In our experiments only one application of N was made to trees showing N deficiency, so that more rapid translocation from the leaves could have been expected.

The results of the spring and fall foliar applications are different with respect to the effect of sucrose. Since the leaves used in the fall foliar applications were old and differentiated, the addition of sucrose might be expected to stimulate leaf metabolism, but even so the absorption of nitrogen was relatively slow. Twenty-four hours after the applications only 30 to 38 percent nitrogen was absorbed, i.e., much less than the 82 percent nitrogen that was absorbed after 12 hours in the spring applications.

This experiment is a preliminary study of the absorption of urea by Fireside apple leaves; further studies on a more intensive scale should be made to understand the mechanism of foliar absorption of nutrients. A dipping method could be tried for foliar applications. Further fractionations of nitrogen compounds and carbohydrates would be an aid to the study of the internal changes of the compounds within the leaves. The sampling method might be improved by treating 100 leaves on the same tree with urea solutions, and by taking a few discs from each leaf at different times.

SUMMARY AND CONCLUSIONS

Mixed foliar applications of urea, Ra-Pid-Gro, and sucrose were applied to leaves of two-year-old Fireside apple trees in the spring and fall of 1951, to study the absorption of nitrogen by leaves.

Solutions were applied to the leaves with small camel's hair brushes in the spring applications and with an atomizer in the fall. Leaves were then sampled at intervals and nitrogen remaining on the leaf surfaces was washed off and measured.

Results show that nitrogen in urea or Ra-Pid-Gro was readily absorbed in a short time after the treatments were made in the spring applications. About 82 percent of the nitrogen was absorbed within 12 hours and 84 percent within 48 hours. Added sucrose or the phosphorus contained in Ra-Pid-Gro did not affect the rate of absorption.

A different response was obtained in the fall foliar applications with respect to the effects of sucrose on nitrogen absorption. No absorption occurred when urea solutions of 0.1M, 0.2M were used alone; a rather slow absorption was found when 0.4M sucrose was added to these urea solutions. About 30 to 38 percent of added nitrogen was absorbed after 24 hours.

From the above results, it is concluded that absorption of nitrogen by apple leaves may vary with the condition of the leaves.

Total nitrogen content of leaf samples was obtained from the spring foliar applications, but no significant increase in nitrogen content of the treated leaves was found after the treatments were made. It is assumed that the absorbed nitrogen was translocated from the leaves.

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